40 Fluids

40.1 Blood has a dynamic viscosity of $3.3cP$ and a density of $66.2\frac{lb_m}{ft^3}$. What is the kinematic viscosity of blood?

A. $1.0 \times 10^{-6}\frac{ft^2}{s}$

B. $2.3 \times 10^{-6}\frac{ft^2}{s}$

C. $3.4 \times 10^{-5}\frac{ft^2}{s}$

D. $1.1 \times 10^{-3}\frac{ft^2}{s}$

Look up kinematic viscosity and dynamic viscosity in the reference handbook and use the formula:

$$\nu = \frac{\mu}{\rho}$$

where ν is kinetic viscosity, μ is dynamic viscosity, and ρ is density. The dynamic viscosity has been given in units of cP. For the final answer to be in the desired units, convert the dynamic viscosity to $\frac{lb_f \cdot sec}{ft^2}$. Use the conversion factors in the reference handbook by searching measurement relationships as necessary.

$$\mu = (3.3cP)\left(\frac{0.001Pa \cdot sec}{1cP}\right)\left(\frac{14.7\frac{lb_f}{in^2}}{101,325Pa}\right)\left(\frac{144in^2}{1ft^2}\right) = 6.9 \times 10^{-5}\frac{lb_f \cdot sec}{ft^2}$$

Apply the kinematic viscosity formula. In order to eliminate lb_m and lb_f from the units, it is necessary to multiply by $\frac{32.2\frac{lb_m \cdot ft}{sec^2}}{1lb_f}$, an expression that is equal to 1.

$$\nu = \frac{\mu}{\rho} = \left(\frac{6.9 \times 10^{-5}\frac{lb_f \cdot sec}{ft^2}}{66.2\frac{lb_m}{ft^3}}\right)\left(\frac{32.2\frac{lb_m \cdot ft}{sec^2}}{1lb_f}\right) = 3.4 \times 10^{-5}\frac{ft^2}{sec}$$

Answer C

40.2 A pump delivers $200gpm$ of water at $130ft$ of total dynamic head, operating from 7am-7pm Monday through Friday. The pump is 80% efficient and the motor is 93% efficient. What is the annual cost of operation at $0.13 per kWh?

A. $2670

B. $3490

C. $3750

D. $5030

The cost is a function of electrical power and time, and electrical power is a function of hydraulic horsepower (aka water horsepower i.e. whp) and efficiency. Start by calculating the water horsepower based on volume flow rate and feet of head provided by the pump:

$$whp = \frac{Q\Delta h}{3960} = \frac{(200)(130)}{3960} = 6.566hp$$

Note the volume and head units must be in GPM and feet, respectively, to use this "rule of thumb" equation. Therefore units need not be shown, provided they are confirmed to be correct prior to use.

Recall that brake horsepower, bhp, depends on water horsepower, whp, and the efficiency of the pump, η_p. Similarly, the electrical power, P_{elec},depends on brake horsepower, bhp, and motor efficiency, η_m.

$$bhp = \frac{whp}{\eta_p}$$

$$P_{elec} = \frac{bhp}{\eta_m}$$

Put these together, substitute, solve, and convert to KW:

$$P_{elec} = \frac{whp}{\eta_p \eta_m} = \frac{6.566hp}{(.8)(.93)} \left(\frac{.746KW}{1hp}\right) = 6.58KW$$

To find the annual cost, multiply by time and the unit rate of electricity:

$$Cost = (6.58KW)\left(\frac{12hrs}{day}\right)\left(\frac{5days}{wk}\right)\left(\frac{52wks}{yr}\right)\left(\frac{\$0.13}{KWH}\right) = \$2669\,per\,year$$

Answer A